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Method analysis of surveying of mineral storages in open-pit mining

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Abstract. The final products of mining enterprises are stored in open or closed areas-mineral storages. The duties of the surveyor service include monitoring of the volume of mineral, which is placed in storage. Requirements for the method of shooting and the accuracy of the received results are regulated by normative documents. Taking into account the introduction into production of modern geodetic technology survey of storage can be realized both methods of classical geodesy (the method of perpendiculars, total station survey) and with the use of GPS receivers, scanning laser systems, unmanned aerial vehicles or drones. In the article is given brief characteristic of specified survey methods and possible scope of their use. Based on the characteristic features of the storage: its form and type and taking into account possible method of measurement production (automated, non-automated) was developed method of selecting of survey. So, on the example of the open transshipment ore storage taking into account its form – medium and type – open and predominant use of automated methods of measurement production are survey methods recommended. Based on the results of the calculation of the storage volume was made the conclusion about compliance of received results with requirement of normative documents.

1. Introduction

Currently, the mining industry is experiencing an increase in the productivity of enterprises, this is due to the involvement of poorer ore reserves in the development. This leads to an increase in the intensity of mining operations, the need to place more of the final product of the enterprise and minerals in storages. One of the tasks of the survey service at the enterprise is the production of measurements of the volume of extracted ore mass, including in ore storages.

2. Material and methods

Measurements are made by the company's survey service in order to control the correctness and completeness of the Deposit development and execution of the mining plan. Periodicity of the surveying is determined by the amount of production and overburden volumes. At large and medium-sized mining enterprises the surveying is performed monthly, by small volumes-1 time per quarter. Independently of the used method of surveying, location of clear outlines, received by surveying points, bases of photographing or stereo pairs, must not exceed 1mm in plan, and for fuzzy outline – 1.5 mm. The height difference of pickets is allowed no more than 0.4 m [1–3].

The technology of surveying measurements consists in comparing of the volumes of residues of minerals in storage at start and at the end of the reporting period. Calculations of the volume of residues of minerals in storage are based on survey data [4–5].

Depending on the shape and complexity of the object, the presence of possible obstacles in the form of overpasses, galleries, communications, various technologies are used for the production of surveys – traditional and modern surveying technologies. Traditional methods include perpendicular and total station methods, while modern methods include satellite technologies, laser scanning, and photogrammetry (ground and air). These types of surveys are made using laser rangefinders, optical and electronic total stations, GPS receivers, laser scanners, unmanned aerial vehicles or drones [6–19].

The analysis of various technologies of surveying production is carried out, on these grounds is the systematization of technical means performed (Table 1) [8, 10–11].

Table 1. Surveying methods.

Way of surveying	Applied equipment	Advantages	Disadvantages
Classical geodesy: perpendicular, total station	Laser range finder, optical and electronic total station	good knowledge, low cost, reliability.	high labor intensity of surveying, not always ensuring the safety of surveying, low information content, depending on weather conditions.
Technologies global navigation satellite system (GNSS)	GPS receiver	measurement independence, efficiency, automation, high measurement accuracy	unstable satellite signal during surveying, it is not always possible to ensure the safety of surveying
Ground-based laser scanning	Scanning system	high measurement accuracy; safety of the performer by surveying; high surveying performance	extremely large excess volume of received information, high cost of work, dependence on weather conditions
Aerial survey	Unmanned aerial vehicle, drone	effective in hard-to-reach, unsafe and moving objects, large areas, fast-moving processes, reliability and sufficient accuracy	dependence on meteorological conditions, complex structure of organizational work, the need for large computing power of personal computers

Analyzing the data shown in the table, it should be noted that surveys using electronic total stations and geodetic GPS/GLONASS receivers are the most common for the production of surveys of various mining facilities. This is due to high performance and relatively simple processing of the received information.

The use of laser scanning and aerial survey systems using manned aircraft requires a large amount of material, organizational and time costs for the production of surveying. Therefore, their use is not profitable for small mining enterprises. At the same time are extensively unmanned aerial vehicles (UAVs) with a relatively low cost and an ability of operational deployment of equipment complex implementing. This will significantly reduce the labor intensity and cost of performing work on territories with an area of up to 1–2 km^2 [9, 15–19].

3. Results and discussions

The purpose of this work is consideration of the possibilities of modern geodetic equipment in the production of surveys of various mining facilities.

The object of research is an open transshipment storage of apatite ore.

To select the method of production of surveys on the object, their analysis was performed according to the following indicators: the shape and type of the object, the method of measurement. The results are shown in table 2.

Based on the performed analysis is it possible to draw the following conclusions:

1. By surveying on simple objects of closed and open type is it better to use the 1 and 2 methods of surveying.

2. Surveying of medium-sized objects is carried out using traditional and modern methods of surveying.

It is better to survey complex open-type objects using 3, 4, and 5 methods, by surveying of the closed-type storages, it is not possible to use GNSS technologies.

According to the proposed indicators object of the work has medium shape and belongs to the open type. In accordance with table 2 the following methods can be used for surveying: total station, GNSS, laser scanning and an aerial survey.

Table 2. Selecting of surveying method.

Way of surveying	Object form			Measurement method		Object type	
	simple	medium	difficult	non-automated	automated	opened	closed
1. Perpendiculars	+	–	–	+	–	+	+
2. Total station	+	+	–	+	+	+	+
3 GNSS	–	+	+	–	+	+	–
4. Laser scanning	–	+	+	–	+	+	+
5. Aerial survey	–	+	+	–	+	+	+

The surveying was performed using the following equipment:

- total station – electronic total station Leica TS06 plus Arctic 5";
- GNSS-two-frequency GNSS receivers operating in real time (Real Time Kinematic):mobile receiver (Leica GS08) from the base receiver (Leica GR10).The volume of mineral resources for these two methods of survey is determined by the method of vertical sections in the GIS GEOMIX software package.
- laser scanning with the Leica HDS4400 laser system with volume calculation in the I-Site Studio software;
- aerial survey - DJI PHANTOM 4 Pro with data processing in the Agisoft Metashape software package and volume calculation in the Credo master Plan.

The results of determining the volume of the mineral storage are shown in table 3.

Table 3. Results of volume determination.

Way of surveying	Volume of storage, m^3	Relative error in determining of volume, %
Total station	82087	2.6
GNSS	82190	2.5
Lasers canning	84718	1.0
Aerial survey	84845	0.9

To evaluate the accuracy of the definition of the storage volume a received value was compared with the data of operational accounting, which amounted to 86500 m^3.

4. Conclusion

Analyzing the results of calculating the volume of the mineral storage, it can be concluded that all methods, for the accuracy of determining the volume, meet the requirements of the Instructions [1]. By the final choosing of surveying method it is necessary to take into account the time spent on the production of works, the difference in the amount of capital and operating costs for each type of used equipment.

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